



K_{l3} prospects from NA48/2

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NA48/2 plans for the K_{e3} and $K_{\mu3}$ branching ratios and Dalitz plots measurements are discussed. The relative errors for the branching ratios $< 1\%$ are expected.

1 Motivation

In the most precise test of the CKM matrix unitarity:

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 0.9957 \pm 0.002 \quad (1)$$

the result is less than 1 by more than an error, and $|V_{us}|$ contributes near 30% of the total uncertainty. So it is important to measure $|V_{us}|$ with the precision better than 1% to clarify the situation.

The values of $\Gamma(K_{e3})$ and $\Gamma(K_{\mu3})$ are the input for the $|V_{us}|$ calculation (they enter as multiplicative factors), so the next-generation measurements of these rates would improve the precision of the CKM unitarity test. The Dalitz plot shapes are also important, as the decay form factor contributes here.

2 NA48/2 experiment

The main NA48/2 goal is a search for the CP violation in the asymmetry of $\pi^+\pi^+\pi^-$ and $\pi^+\pi^0\pi^0$ Dalitz plots between the kaons of the opposite charge. The additional tasks must not disturb the main data taking process.

The NA48 detector (fig. 1), initially designed for the precise measurement of the direct CP violation parameter $Re(\epsilon'/\epsilon)$, is described elsewhere [1], [2]. The main new features of the NA48/2 stage [3] setup that may be relevant for the K_{l3} measurements are the following:

- The narrow momentum spectrum (60 ± 3 GeV) of charged kaons.
- KAon BEam Spectrometer (KABES), based on the MICROMEGAS technology [4], placed before the decay volume will provide the kaon momentum measurement with $\approx 1\%$ precision. It will give a possibility to reconstruct the kinematics of the decays with neutrino among the products.

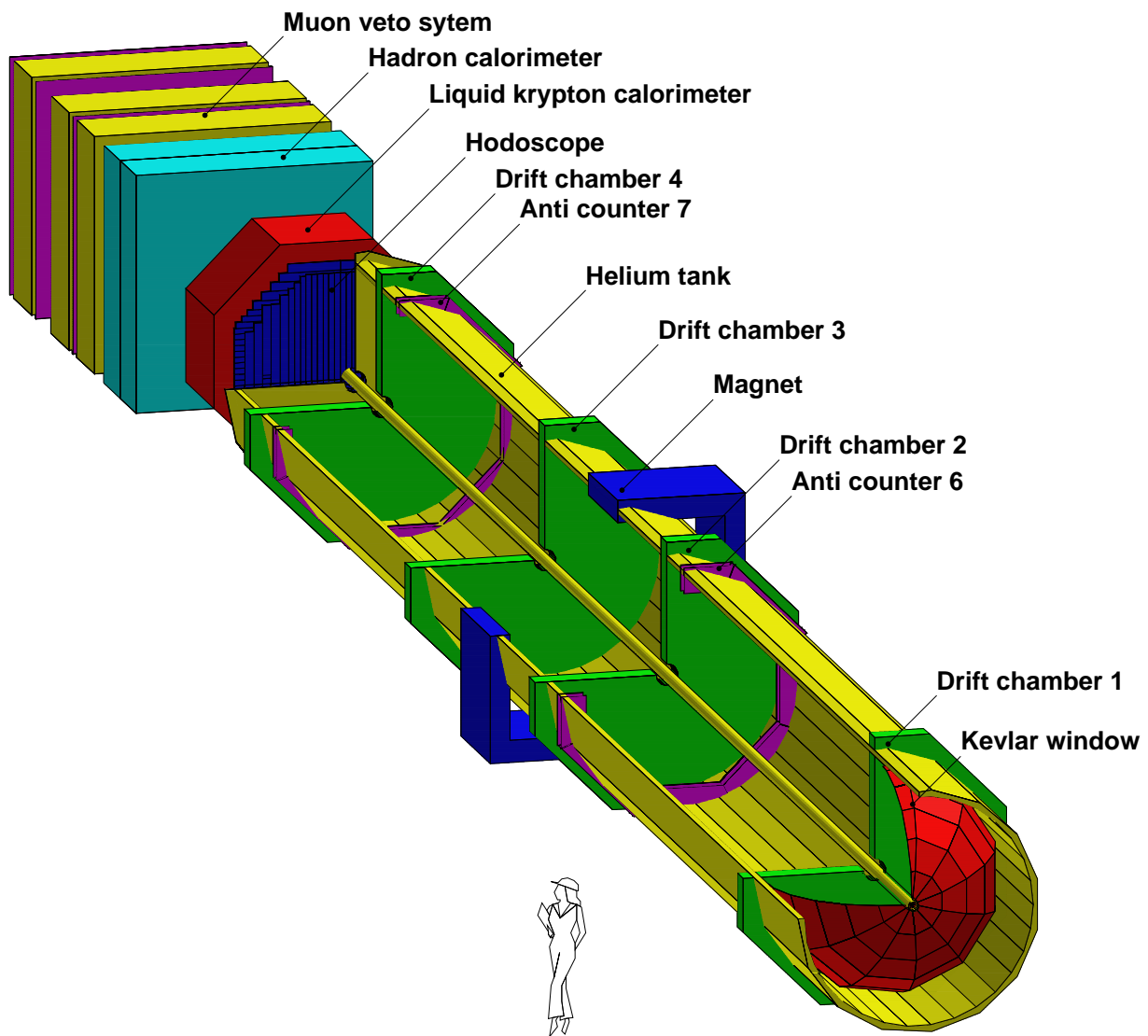


Figure 1. NA48 detector.

3 Measurement with a similar normalizing modes

There are several measurement strategies, discussed now in the NA48/2 collaboration. The choice of the normalizing modes will define the expected sensitivity of the measurement to the results of other experiments (normalizing mode rates) and to the quality of the Monte Carlo acceptance calculations. Moreover, it will define the extra trigger rate that has to be affordable for NA48/2.

One can normalize the branching measurement with the similar decays. In this case we will measure the branching ratios $\frac{Br(\pi^0 e^+ \nu_e)}{Br(\pi^+ \pi^0)}$ and $\frac{Br(\pi^0 \mu^+ \nu_\mu)}{Br(\pi^+ \pi^0)}$.

Pro: the same number of γ -s and charged tracks may decrease the sensitivity to the Monte Carlo acceptance calculations.

The error of the measured fraction Br with B_2 as normalizing one is (ignoring the acceptance errors):

$$\delta Br = \frac{N}{N_n} B_2 \left(\frac{\delta B_2}{B_2} + \sqrt{\frac{1}{N} + \frac{1}{N_n}} \right) \quad (2)$$

Contra: We can not decrease the relative error of K_{l3} fractions to better than 0.007 (PDG error of $Br(\pi^+ \pi^0)$) this way. In fact, the precision can not be better than 1% (the statistics doesn't limit here, but Monte Carlo uncertainty will contribute).

One can measure $\frac{Br(\pi^0 \mu^+ \nu_\mu)}{Br(\mu \nu)}$.

Pro: Better precision of the $Br(\mu \nu)$ (relative error 0.003). May be some cancelling of the Muon Veto efficiency.

Contra: $(\mu \nu)$ event doesn't have γ and the event is not very similar to $K_{\mu 3}$ from the detector point of view. We will rely more on the precision of the acceptances calculation.

4 Using all large modes for normalizing

One can record all the large fractions (with proper downscalings), including $(\mu^+ \nu_\mu)$ **together with the corresponding radiative processes: $\mu^+ \nu_\mu \gamma$, $\pi^+ \pi^0 \gamma$ etc..**

One can see that the sum of all the other charged kaon decays (excluding the exotical ones) is 0.00011 ± 0.00013 . This contribution is negligible for our task.

Assuming that the sum of the 6 largest modes is ≈ 1 , we may calculate the specific large branching ratio Br_x as follows:

$$Br_x = \frac{N_x D_x / A_x}{\sum N_i D_i / A_i} = \left(\sum \frac{D_i}{D_x} \frac{A_x N_i}{A_i N_x} \right)^{-1} \quad (3)$$

Here N_i is the number of reconstructed i -th mode decays, A_i is the acceptance of the mode, D_i is the corresponding downscaling factor. The sum is running over the first 6 modes, indexed by i .

The expression for the error is:

$$\frac{\sigma Br_x}{Br_x} = \sqrt{(1 - Br_x)^2 \left(\left(\frac{\sigma A_x}{A_x} \right)^2 + \frac{1}{N_x} \right) + \sum_{i \neq x} Br_i^2 \left(\left(\frac{\sigma A_i}{A_i} \right)^2 + \frac{1}{N_i} \right)} \quad (4)$$

In the very optimistic case the acceptance calculation precisions may reach per mille level, so to have a compatible statistical error one needs not more than 10^6 events for each large mode (or less than 10 events per burst in each mode, as normally NA48 takes 200 000 - 300 000 bursts per year).

5 Possible triggers and statistics

The preliminary Monte Carlo estimation of the particle fluxes gives the following results. In the decay volume of 108 meters there will be near 1.04×10^6 charged kaon decays and about 1.75 times more pion decays. From the test run 2001 year we expect a considerable flux of muons from target also, but it will be much weaker in 2003 due to the beam line development.

#	Mode	acceptance	events/burst
1	$\mu^+ \nu_\mu$	76 %	503000
2	$\pi^+ \pi^0$	22 %	48000
3	$\pi^+ \pi^+ \pi^-$	26 %	15000
4	$\pi^+ \pi^0 \pi^0$	7 %	1300
5	$\pi^0 \mu^+ \nu_\mu$	24 %	8000
6	$\pi^0 e^+ \nu_e$	17 %	8500

A large statistics of $\pi^+ \pi^+ \pi^-$ (billions) and $\pi^+ \pi^0 \pi^0$ will provide a chance to make a precise tuning of the Monte Carlo (beam geometry, acceptances, spectra).

Maximum trigger readout rate is estimated to be 60K in 5.2 s spill. Main triggers for 3π decays may use 50-55 K (the purity of the trigger for $\pi^+ \pi^+ \pi^-$ in the worst case is 0.4, for $\pi^+ \pi^0 \pi^0$ the expected trigger rate is 16K). So only few thousand triggers could be used for other purposes.

If we consider a rather conservative scenario of data taking (simple, but efficient triggers with proper downscalings), we can collect more than 20 good events for each of the above modes, taking less than 1700 extra triggered events in total. With more advanced trigger logics (almost ready at present) we will collect 10 times more K_{l3} events to measure the Dalitz plot shapes, taking less than 2000 extra triggers.

6 Conclusion

- The K_{e3} and $K_{\mu3}$ branching ratios and Dalitz plots measurement is foreseen in the charged kaon beam of NA48/2 experiment.
- The dominating contribution to the uncertainties may be systematic rather than statistical error. Assuming the reasonable level of the Monte Carlo error one can set a limit on the statistics we really need. It is 10^6 per normalizing mode and 10^7 per K_{l3} mode (10 times more for Dalitz plots).

- The data can be taken without disturbing the main NA48/2 tasks. The additional output triggers rate will be less than 3% of the total one.
- The relative branching error is expected to be between 0.01 and 0.001, depending on the Monte Carlo precision.

References

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2. J. R. Batley *et al.* [NA48 Collaboration], A precision measurement of direct CP violation in the decay of neutral kaons into two pions, Phys. Lett. B **544** (2002) 97 [arXiv:hep-ex/0208009].
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